Solar Tracker Robot using Microcontroller

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***Abstract*— Shortage of non-renewable fuel in the future is an upcoming global issue; therefore renewable energy such as solar energy has gradually replaced non-renewable energy. However, the output power provided via the photovoltaic conversion process depends on solar irradiation. The objective of this project is to design and develop an automatic Solar Tracker Robot (STR) which is capable to track maximum light intensity. The efficiency of the solar energy conversion can be optimized by receiving maximum light on the solar panel. The main components of the robot consist of microcontroller namely PIC16F877A, sensors, servo motors and digital compass. This robot is programmed to detect sunlight by using two Light Dependent Resistors (LDR). Servo motor aligns the solar panel to receive maximum light. Digital compass is used to detect the position of the robot. Two modified DC servo motors will move the robot back to the original position once the robot is out of position. The robot is programmed using MPLAB IDE v8.30. Analysis on the power conversion of solar panel is being carried out by using Fluke 1750 power quality recorder.**

***Keywords*—Solar Tracker Robot; Solar Panel; Sunlight; Servo Motor; Digital Compass.**

I. INTRODUCTION

Due to the limited supply of non-renewable fuels, scientists nowadays are searching for alternative energy resources. Besides, fossil fuels have many side effects, since the combustion products produce pollution which can cause acid rain and global warming. Therefore, conversion to clean energy sources such as solar energy would enable the world to improve the quality of life throughout the planet Earth.

Solar energy is an unlimited supply and nonpolluting source; solar power is being moderately used compared to hydro and wind power. This can be attributed to the low conversion efficiency of solar cells and high cost. There are two ways for maximizing the rate of useful energy; optimizing the conversion to the absorber level by properly choosing the absorber materials, and increasing the incident radiation rate by using tracking systems [1].

Solar cells are traditionally fixed on rooftop or fixed on ground. As a result, solar cells unable to receive maximum light as position of sun changing varying with time. The research to date has tended to focus on the efficiency of the solar cell. This paper will present the STR which is designed to improve the efficiency of solar power by allowing solar cells to align with the sun's movements to track optimum sunlight. The tracking system was designed as a normal line of the solar cells which will always run parallel within the ray of the sun. The orientation of the photovoltaic panels may increase the efficiency of the conversion system from 20% up to 50% [2, 3, 4, 5].

The STR for this project does not need any installation; since it is portable and can be located in a free space exposed to direct sunlight. The STR will adjust the position automatically. This task will accurately be done with the aid of digital compass. The solar panel moves in one axis, rotates from east to west, while the base of the robot will always ensure that the front of robot points to north.

II. LITERATURE REVIEW

Previously, there are many projects related to solar tracking system that improve the solar tracking system. Following are the previous projects.

A. Microprocessor Based Solar Tracking System Using Stepper Motor

The microprocessor is being used to control the tracking system by interfaced with others components. The advantage using microprocessor is that many functions can be added on to it by adding extra components [6]. However, it requires external components to implement program memory, RAM and ROM memory, input and output port, and ADC. This will cause high cost of the project, besides increasing the complexity of the project.

B. Miniature Solar Tracker

This solar tracker was microcontroller based and single-axis tracking systems using DC motor. The single-axis tracking systems spins on their axis to track the sun, facing east in the morning and west in the evening. This project is cheap and simple in terms of controlling, since the solar tracking system is supported by a tripod [7]. This project does not have an intelligent feedback to control the position of the solar tracker if it is out of position, so it cannot track the maximum sunlight.

C. Different Tracking Strategies for Optimizing the Energetic Efficiency of A Photovoltaic System

This project was a fuzzy logic neural controller and dual-axis tracing systems. The two-axis tracking systems are able to follow very precisely the sun path along the period of one year [8]. Therefore it is more efficient than the single-axis tracking systems, yet more expensive. This is because they are using more electrical and mechanical parts. Another disadvantage is the difficulty and complexity of the control part increases.

D. Solar Tracker Robot Using Microcontroller

STR is microcontroller based and built to move the solar panel in one axis, which is from east to west and vice versa. Servo motor is the actuator used to move the solar panel due to the high torque and small in size. The STR will automatically adjust the position of the robot so that it always faces the same direction. This will ensure the solar panel receiving optimum sunlight if external force is applied to move the STR.

III. METHODOLOGY

In this project, the tracking system of the robot will be controlled by two Light Dependent Resistors (LDRs) act as input signals, and a servo motor as an actuator to rotate the solar panel. Besides, the navigation of the robot most of the time will be controlled by using digital compass data to correct the error. Meanwhile, the digital compass data will give feedback to the microcontroller using Inter Integrated Circuit (I^2C) interfacing. In the controller part, it consists of PIC16F877A chip. The whole circuit includes the LDR, servo motors, and the digital compass will be controlled by this chip.

A. System Architecture

Fig. 1 shows the architecture of the whole system including light sensors, digital compass, limit switches, three servo motors, and servo motor driver. Two major parts, from the figure are tracker and the base. The PIC16F877A chip on the control circuit is the main processor where it will control the whole system. I^2C is used in this architecture to interface with the slave devices (Digital Compass Module HMC6352).

B. Sensor Arrays

The LDR sensors will be setup as Fig. 2. When both sensors are equally illuminated, their respective resistances are approximately the same. When either sensor falls in shadow, its resistance increases beyond the range and the PIC microcontroller will activate the motor to drive both sensors under even illumination [9]. When west cell (W) is in shadow, tracker rotates to east, while when east cell (E) in shadow, tracker will rotate to west. The flow chart for moving solar panel is shown in Fig. 3.

C. Digital Compass

Digital compass is used to read the current position of the robot. The STR is set to heading north, which is 0° so that solar panel will track the sunlight form east to west. Once the STR is not in the set point, the operation as Fig. 4 will operate.

D. Main Board Control Unit

Fig. 5 shows the schematic diagram for the STR system. The system consists of microcontroller, two LDR sensors, digital compass, motor driver L293D, servo motors, limit switches, and others components.

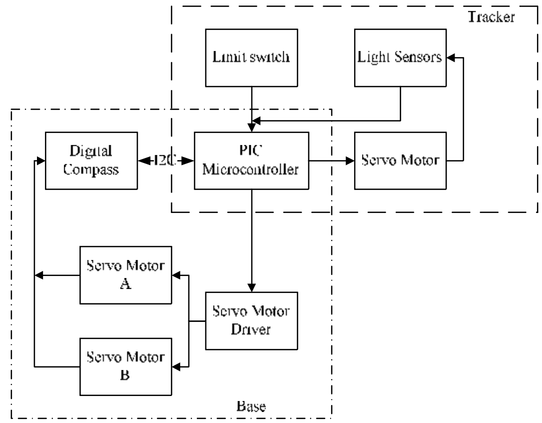

Figure 1. Solar tracker robot control architecture

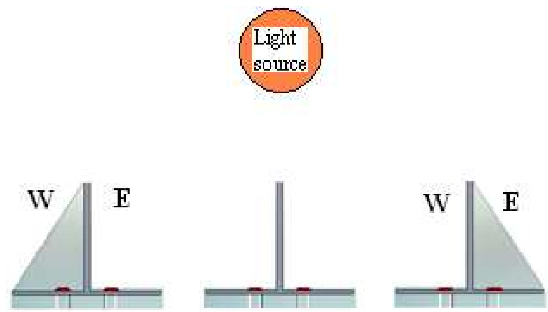

Figure 2. Condition of sensors array

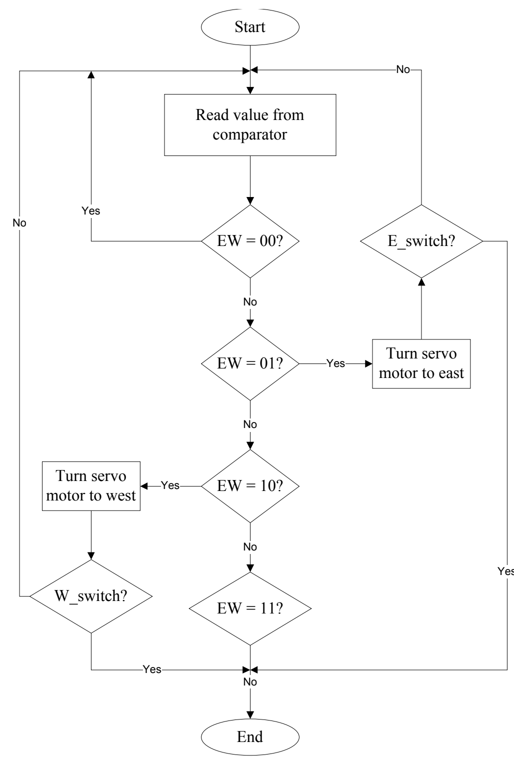

Figure 3. Solar panel control architecture

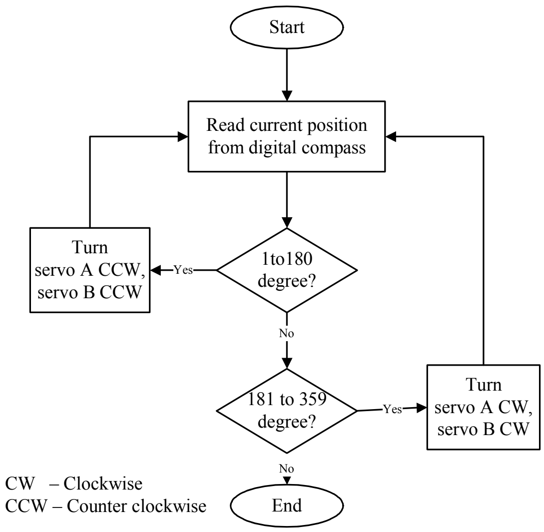

Figure 4. Base control architecture

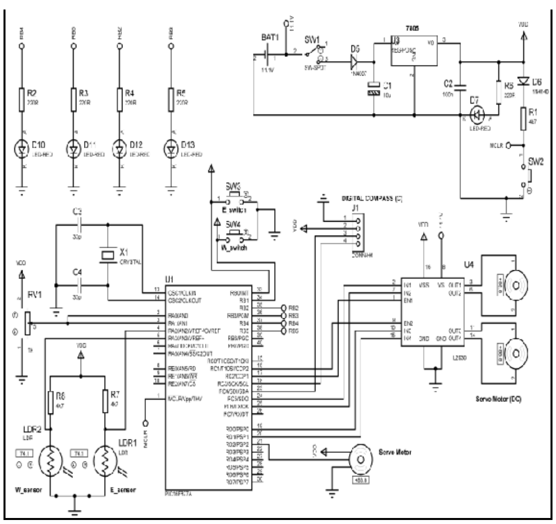

Figure 5. Main board control unit circuit schematic

IV. Result And Analysis

A. Analysis on Light Dependent Resistor

The resistance value and voltage for different types of light source are shown in Table I. The output voltage when the LDR is under shadow is 1.15V, therefore the reference voltage which is to be input for comparator is set to 1.0V.

TABLE I.
RESISTANCE AND VOLTAGE VALUE FOR LDR

Types of Light Source	Resistance, kΩ	Voltage, V
Direct sunlight	0.19	0.19
Cloudy	0.60	0.57
Shadow	1.40	1.15
Natural light (Ambient light)	5.04	2.60
No light (Complete darkness)	8.00	3.20

B. Analysis on Solar Panel

Data is collected using Fluke 1750 power quality recorder for one day, which is on 22 March 2010. Data is taken from 9 a.m. to 4 p.m. for 8 samples data. The power efficiency of solar panel can be calculated using (1), while the average power efficiency can be calculated using (2).

$$A = \frac{P_2 - P_1}{P_1} \times 100\% \cdot \quad (1)$$

$$B = \frac{\sum (P_2 - P_1)}{\sum P_1} \times 100\% \cdot \quad (2)$$

Where P_1 = Power produced by the fixed solar panel (Watt) and P_2 = Power produced by the solar panel attached to solar tracker (Watt).

The increments of power efficiency are shown in Table II. The average power efficiency for 22 March 2010 is 19.26%. Referring to Table II, the increments of efficiency are significant from 9 a.m. to 11 a.m. This is because STR is tracking the maximum sunlight compared to the fixed solar panel. However, from 12 p.m. to 4 p.m., there is only a slightly increase in efficiency due to the fixed solar panel is receiving almost the same intensity of sunlight as solar panel on STR. The temperature is recorded to show that higher the temperature, higher the performance of solar panel. The comparison graph of power generated by tracking solar panel and fixed solar panel is shown as Fig. 6.

TABLE II.
DATA COLLECTED FOR 12/1/2011

Day 1 22/3/10	9 am	10 am	11 am	12 pm	1 pm	2 pm	3 pm	4 pm
Fixed Solar Panel								
Voltage, V_1 (V)	7. 16	5. 8	11.4	12.41	10.56	12.56	11.68	9. 46
Current, I_1 (A)	0.18	0.17	0.17	0.16	0.16	0.16	0.15	0.14
Power, P_1 (W)	1.28	1.00	1.94	1.99	1.69	2.01	1.75	1.32
Tracking Solar Panel								
Voltage, V_2 (V)	11.21	9.9	13.0	12.74	10.65	12.62	11.85	10.0 4
Current, I_2 (A)	0. 20	0.19	0.18	0.17	0.16	0.16	0.15	0.14
Power, P_2 (W)	2.24	1.88	2.34	2.17	1.70	2.02	1.78	1.41
Increase in efficiency (%)	75	88	16	9	0.6	0.5	1.7	6.8
Temp. (°C)	23	25	27	27	28	29	29	25
Location: Power Electronic Laboratory, University Tun Hussein Onn Malaysia (UTHM)								

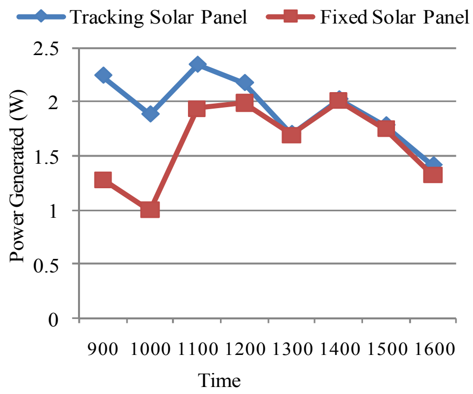

Figure 6. Power comparison between tracking solar panel and static solar panel taken on 12/1/2011

C. Digital Compass

The position of the STR is adjusted automatically. The front of the STR is installed with an analog compass to show the actual position of the robot. Fig 7 shows the STR.

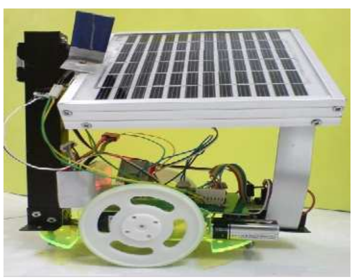

Figure 7. The solar tracker robot and solar panel

V. Conclusion and Recommendations

A. Conclusion

The results of this research indicate that the STR is capable to track the movement of sun and perform a self alignment once the robot is out of position. By attaching a solar panel on the solar tracker robot, the efficiency of the solar panel can be increased. The average power can be increased up to 19.72 percent compare to static.

B. Recommendations

In order to let the STR to function in all weather, the STR should be designed to become water proof so that it will not face any problem during rainy day. This will need more effort on mechanical design.

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